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Waghmare et al.

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(54) **VEHICLE CRADLE ASSEMBLY WITH IMPACT DETACHMENT SCRIPT**

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B62D 27/06 (2006.01)

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CPC ***B62D 21/11*** (2013.01); ***B62D 21/155*** (2013.01); ***B62D 27/06*** (2013.01)

(58) **Field of Classification Search**
CPC B62D 21/11; B62D 21/155; B62D 27/06
USPC 296/187.09
See application file for complete search history.

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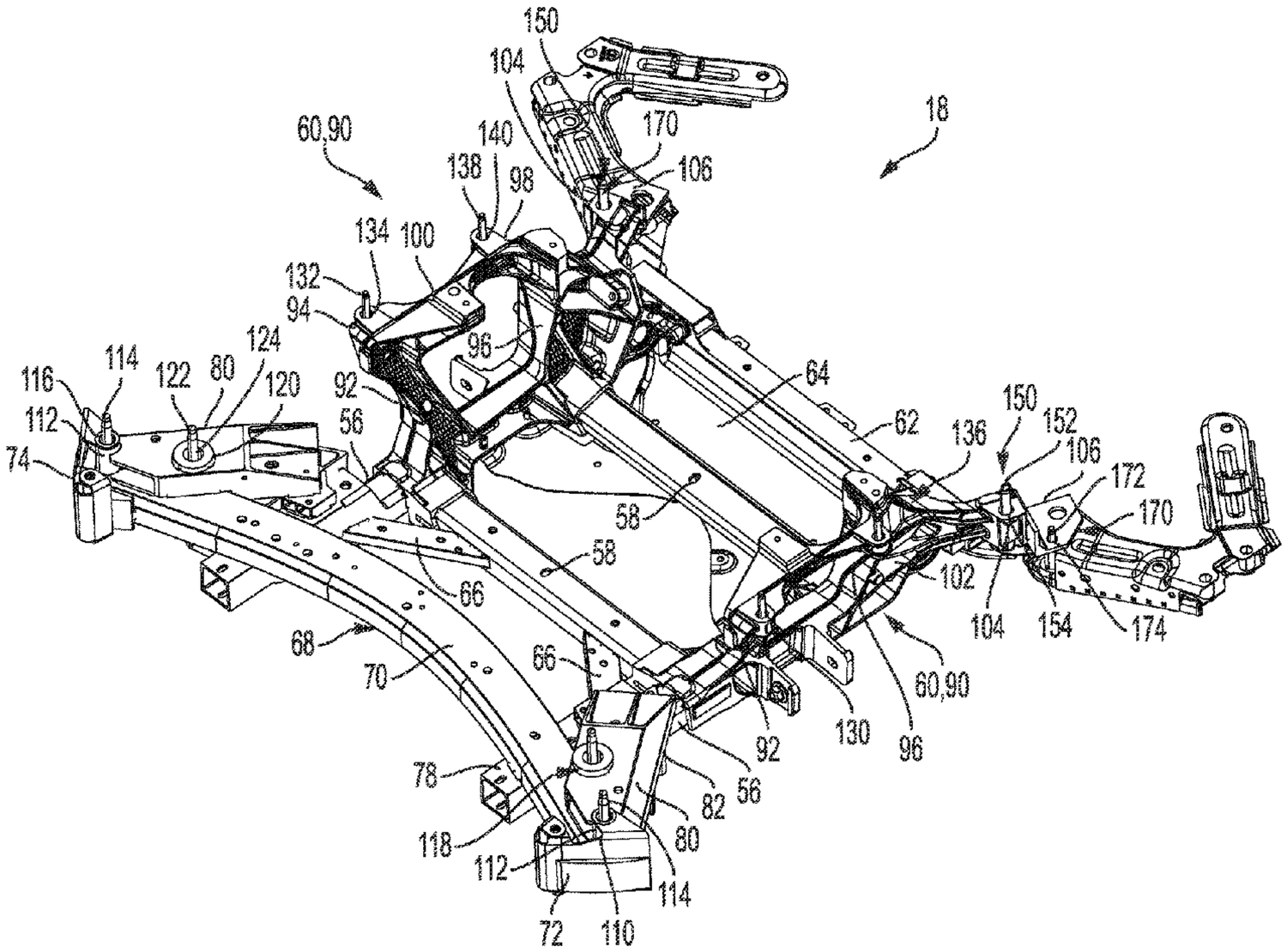
(57) **ABSTRACT**

A structural support system for a vehicle having a longitudinal axis extending from a front of the vehicle to a rear of the vehicle includes a cradle configured to support an engine of the vehicle, a structural side rail assembly having first and second side rails, a first set of six cradle attachments coupling the cradle to the first side rail, and a second set of six cradle attachments coupling the cradle to the second side rail. A predetermined portion of the cradle attachments of both the first and second set of six cradle attachments are designed to intentionally detach during a frontal impact event to facilitate absorbing impact energy and reducing deceleration and passenger compartment intrusion.

17 Claims, 6 Drawing Sheets



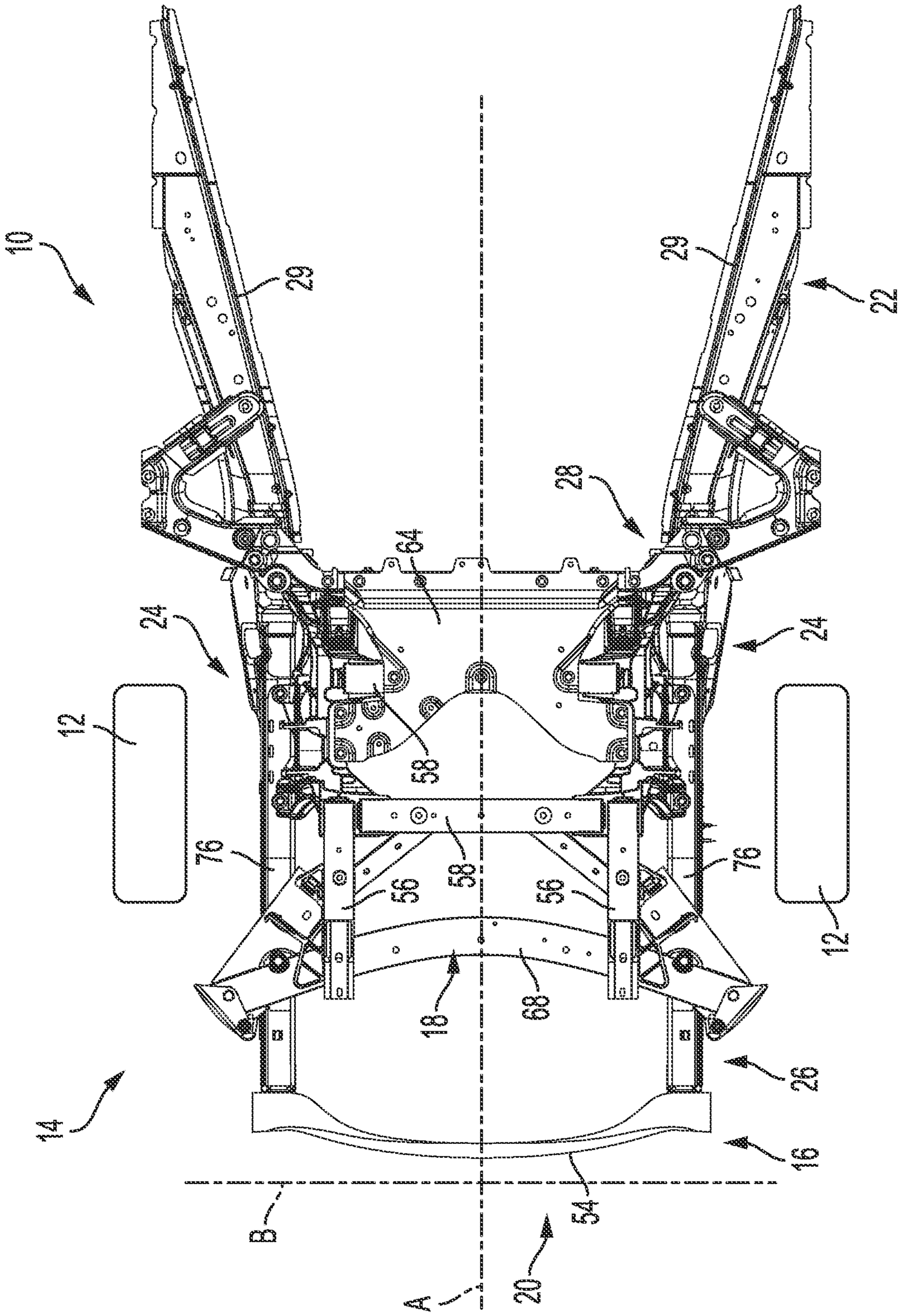


FIG. 1

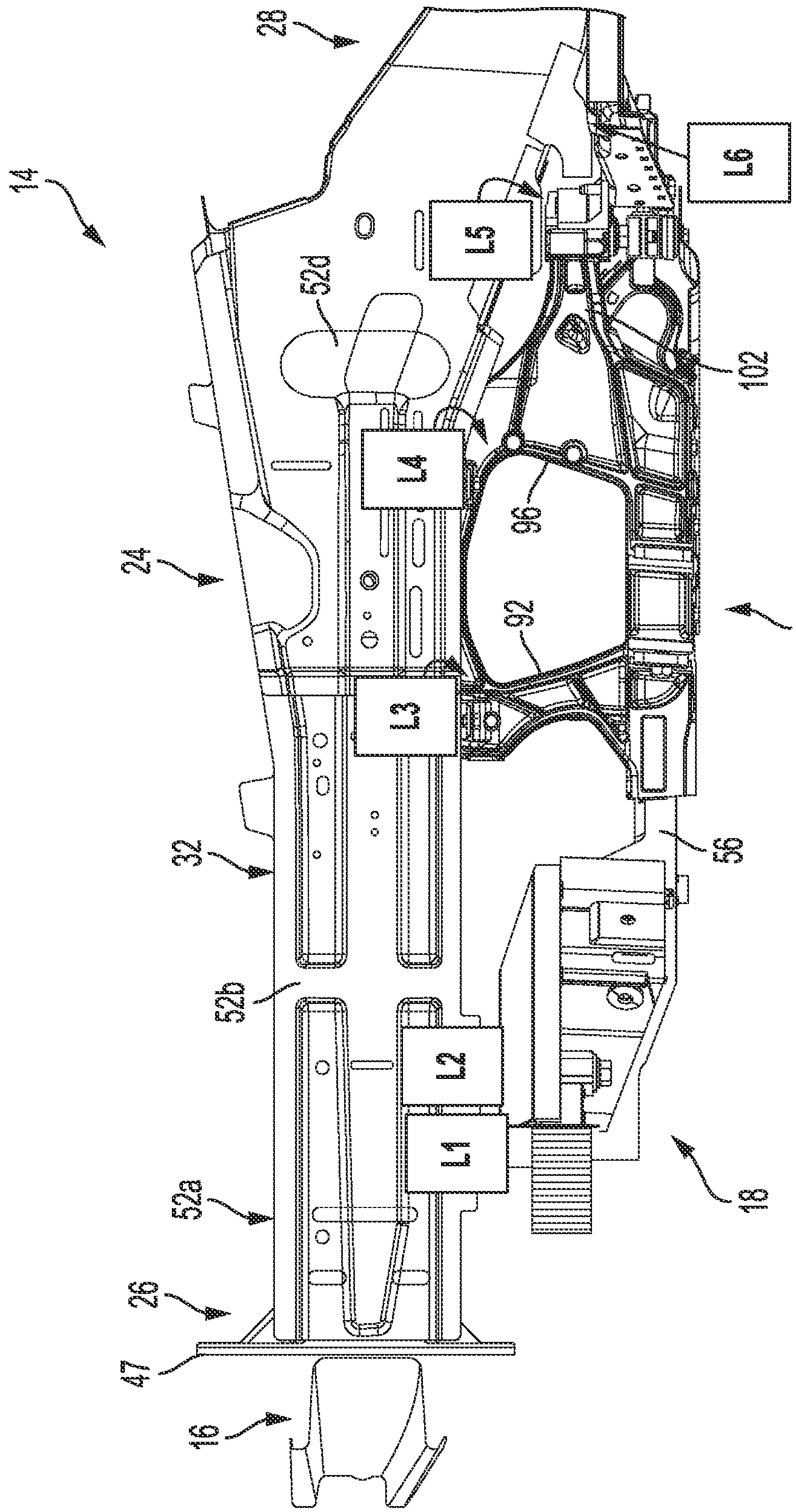
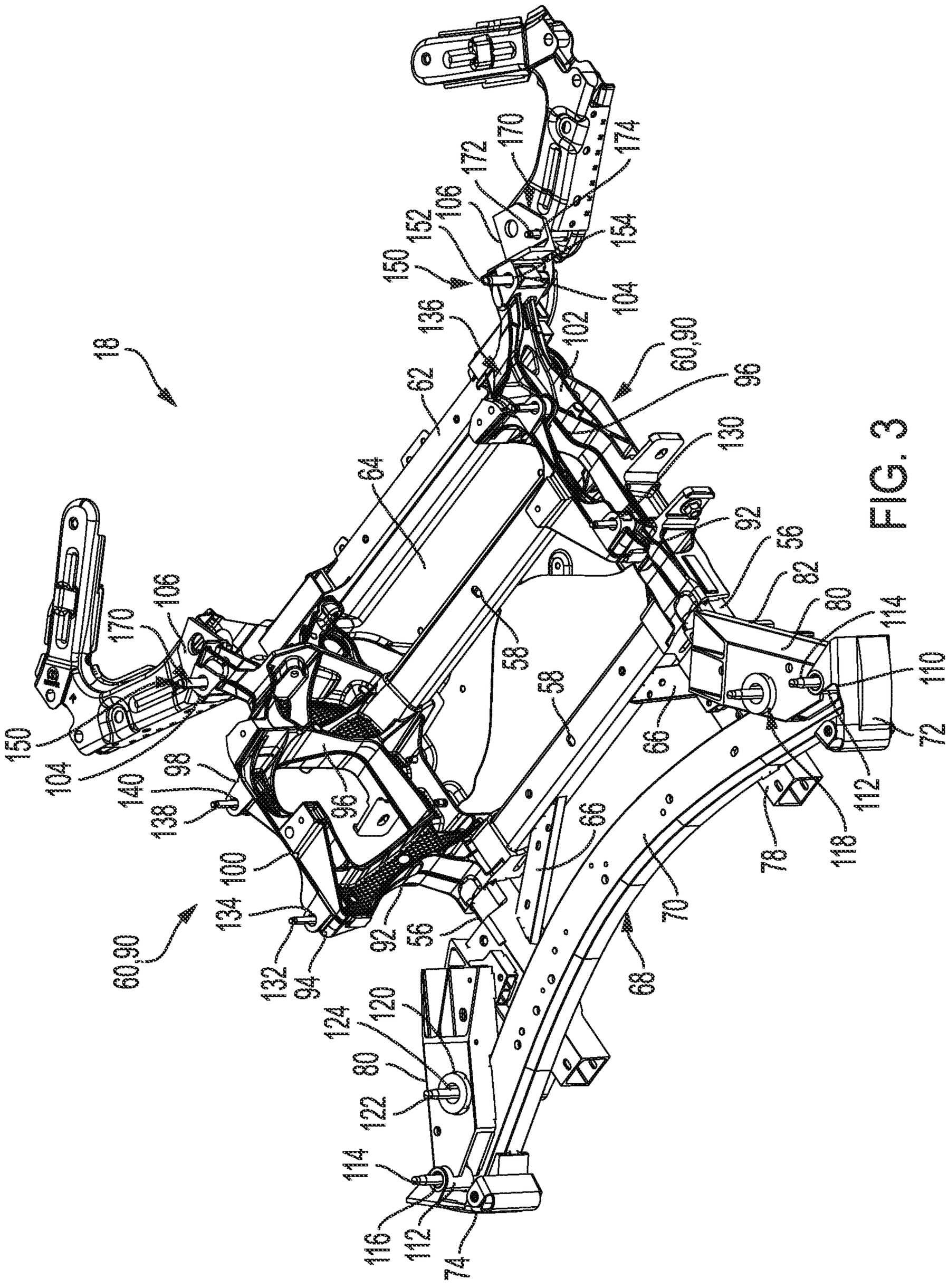


FIG. 2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104
170
106
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66
70
68
124
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74
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118
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110
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130
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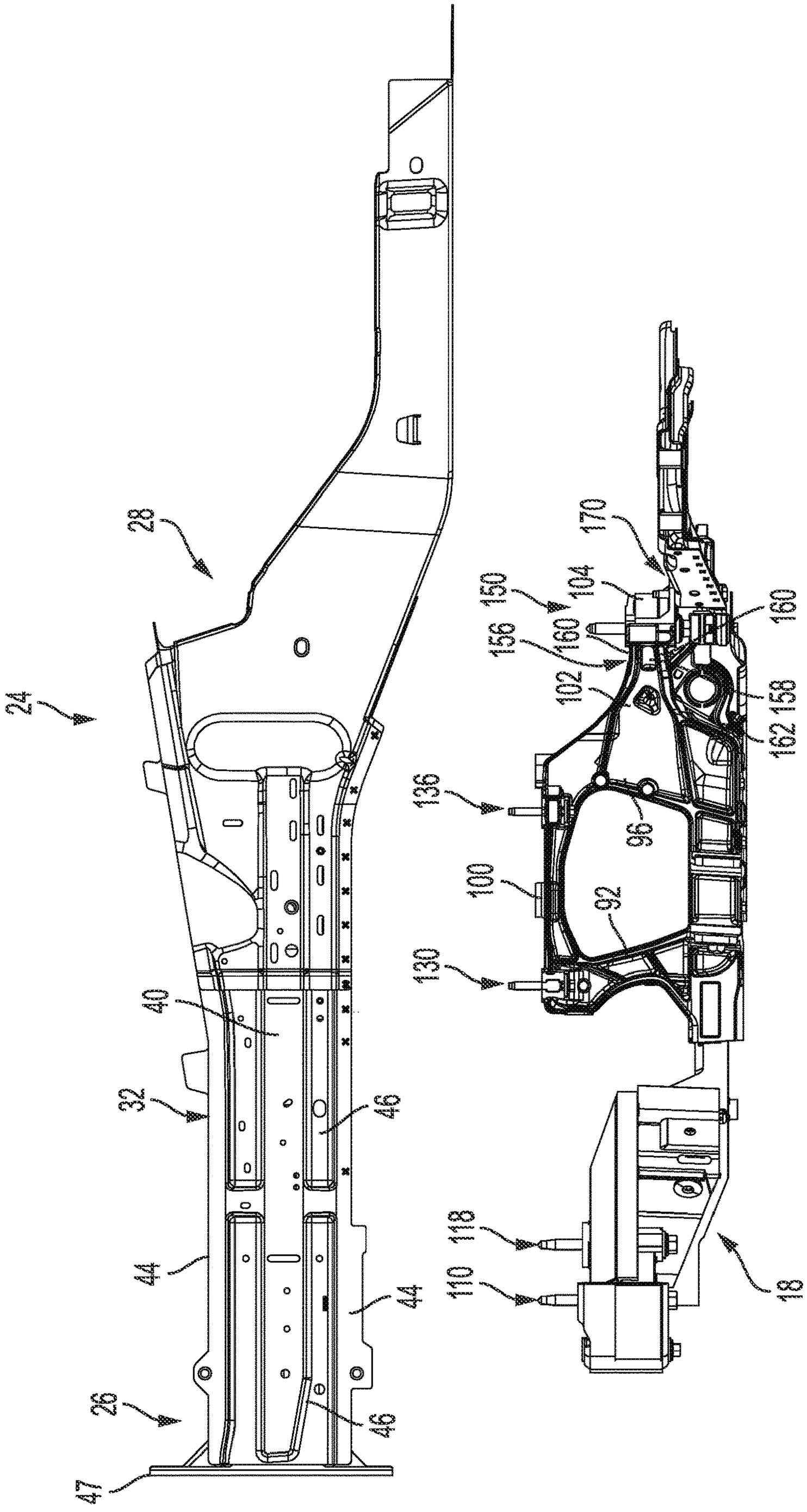
152

FIG. 3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118
110
18

FIG. 4

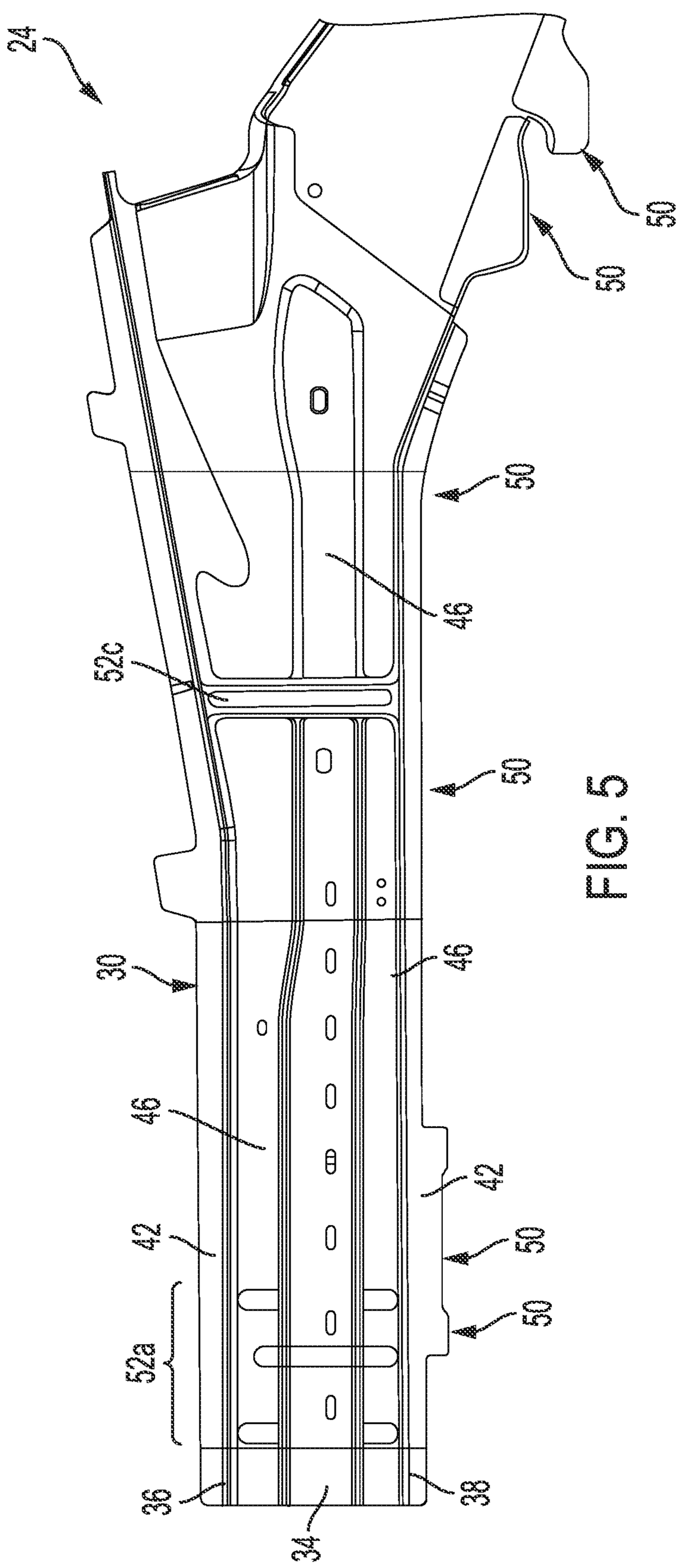

FIG. 5

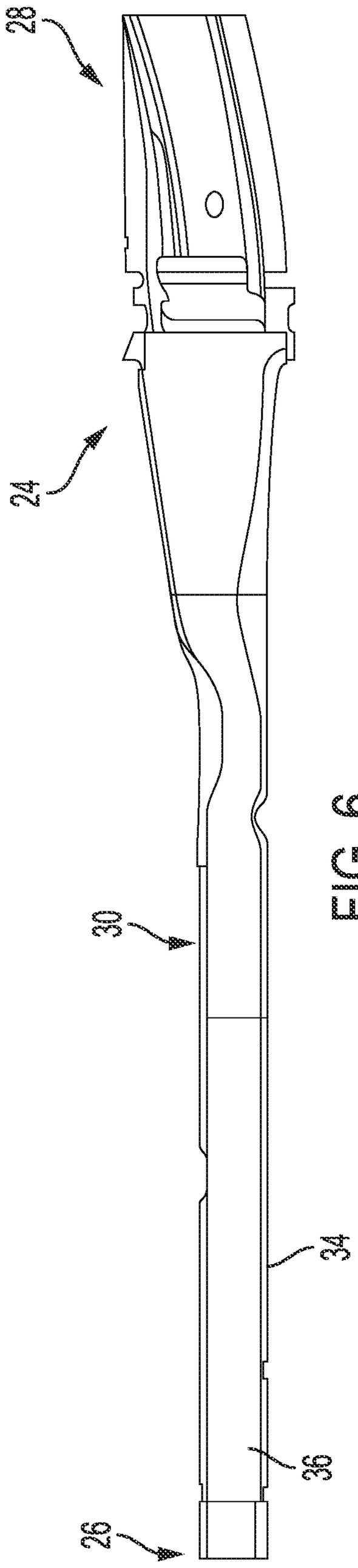

FIG. 6

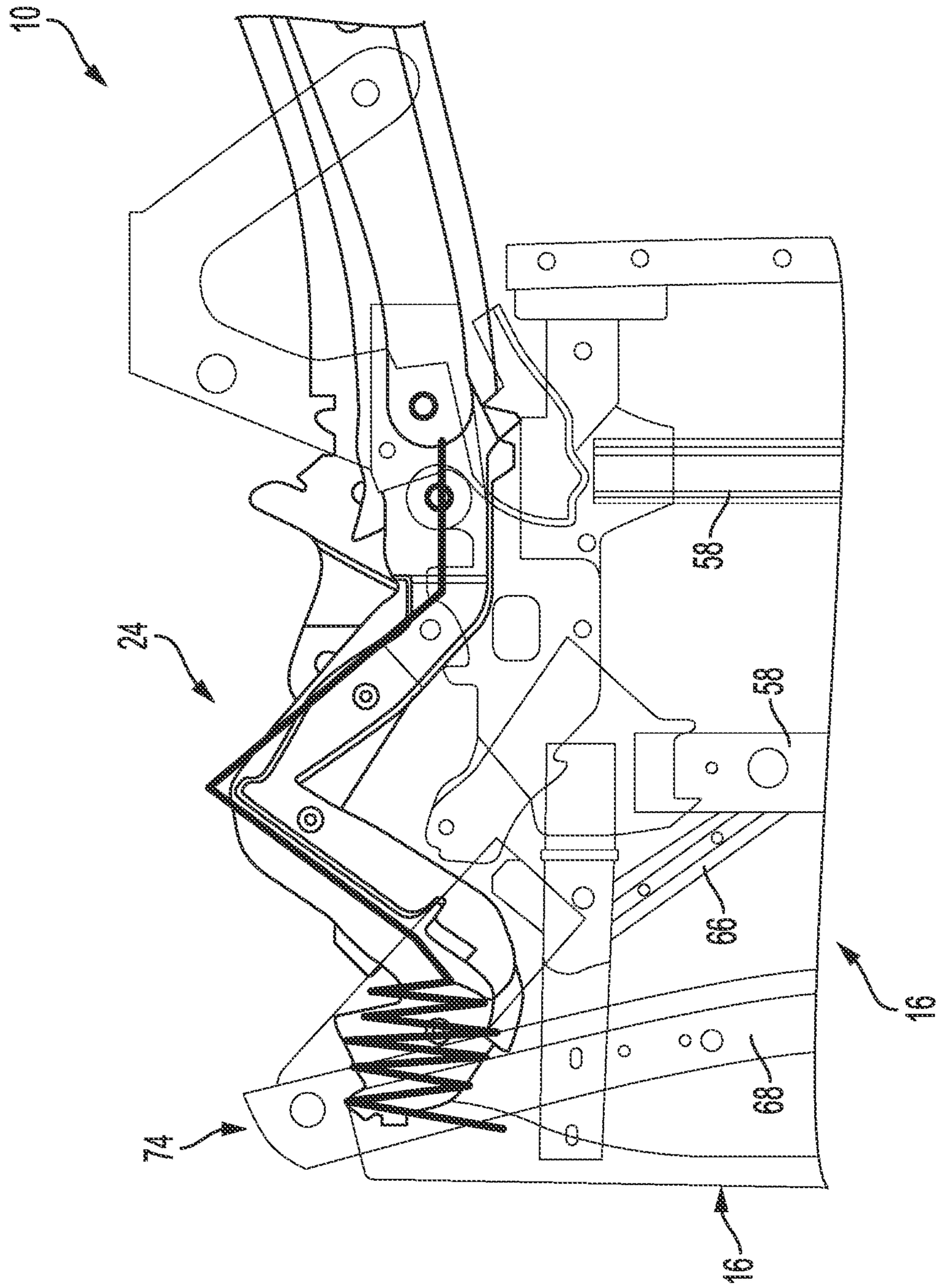

FIG. 7

VEHICLE CRADLE ASSEMBLY WITH IMPACT DETACHMENT SCRIPT

FIELD

The present application relates generally to vehicle structural systems and, more particularly, to a vehicle structural system with a cradle bolt detachment script to improve dynamic crush and performance in frontal impact events.

BACKGROUND

Some vehicles include impact protection structures to absorb energy from an impact event to protect vehicle passengers. In frontal impact events, a large amount of the impact can be directed toward the passenger compartment. Therefore, frontal impact protection structures are typically designed to reduce deceleration for reduced passenger compartment intrusion and improved occupant performance. However, while conventional impact protection structures do work well for their intended purpose, it is desirable to provide continuous improvement in the relevant art.

SUMMARY

According to one example aspect of the invention, a structural support system for a vehicle having a longitudinal axis extending from a front of the vehicle to a rear of the vehicle is provided. In one example implementation, the system includes a cradle configured to support an engine of the vehicle, a structural side rail assembly having first and second side rails, a first set of six cradle attachments coupling the cradle to the first side rail, and a second set of six cradle attachments coupling the cradle to the second side rail. A predetermined portion of the cradle attachments of both the first and second set of six cradle attachments are designed to intentionally detach during a frontal impact event to facilitate absorbing impact energy and reducing deceleration and passenger compartment intrusion.

In addition to the foregoing, the described system may include one or more of the following features: wherein each cradle attachment of the first and second sets of six cradle attachments includes a bolt coupling the first or second side rail to the cradle; wherein the first and second sets of six cradle attachments are identical; and wherein the first and second sets of six cradle attachments include a pair of first cradle attachments, a pair of second cradle attachments disposed rearward of the pair of first cradle attachments, a pair of third cradle attachments disposed rearward of the pair of second cradle attachments, a pair of fourth cradle attachments disposed rearward of the pair of third cradle attachments, a pair of fifth cradle attachments disposed rearward of the pair of fourth cradle attachments, and a pair of sixth cradle attachments disposed rearward of the pair of fifth cradle attachments.

In addition to the foregoing, the described system may include one or more of the following features: wherein the third and fourth pairs of cradle attachments include fasteners configured to detach under the force of the frontal impact event to allow the engine to displace toward a rear of the vehicle; wherein the fasteners are M-10 bolts; and wherein the first and second pairs of cradle attachments include second fasteners configured to maintain the attachment between the cradle and the first and second side rails during the frontal impact event.

In addition to the foregoing, the described system may include one or more of the following features: wherein the fifth pair of cradle attachments includes fasteners configured to maintain the attachment between the cradle and the first and second side rails during the frontal impact; wherein the fifth pair of cradle attachments further includes an attachment arm with a fracture feature configured to fracture during the frontal impact; wherein the attachment arm is cast with a portion of the cradle and includes a proximal end and a distal end, and wherein the fracture feature includes a window defined between two bridges connecting the distal end with the proximal end of the attachment arm; and wherein the first and second side rails each include a plurality of collapsing features configured to facilitate collapsing of the first and second side rails to absorb energy of the frontal impact event.

In addition to the foregoing, the described system may include one or more of the following features: wherein the plurality of collapsing features includes a crush initiator located at a forward end of each of the first and second side rails, a first collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, a second collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, and a third collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact; and wherein the crush initiator is located forward of the first cradle attachment along the direction of the longitudinal axis.

In addition to the foregoing, the described system may include one or more of the following features: wherein the first collapsing feature is located between the second and third cradle attachments along the direction of the longitudinal axis, and wherein the first collapsing feature is configured to collapse the associated first or second side rail in an inboard cross-car direction; wherein the second collapsing feature is located between the third and fourth cradle attachments along the direction of the longitudinal axis, and wherein the second collapsing feature is configured to collapse the associated first or second side rail in an outboard cross-car direction; and wherein the third collapsing feature is located between the fourth and fifth cradle attachments along the direction of the longitudinal axis, and wherein the third collapsing feature is configured to collapse the associated first or second side rail in an inboard cross-car direction.

According to another example aspect of the invention, a structural support system for a vehicle having a longitudinal axis extending from a front of the vehicle to a rear of the vehicle is provided. In one example implementation, the system includes a cradle configured to support an engine of the vehicle, a structural side rail assembly having first and second side rails, a first set of six cradle attachments coupling the cradle to the first side rail, and a second set of six cradle attachments coupling the cradle to the second side rail. A predetermined portion of the cradle attachments of both the first and second set of six cradle attachments are configured to intentionally detach during a frontal impact event to facilitate absorbing impact energy and reducing deceleration and passenger compartment intrusion.

In addition to the foregoing, the described system may include one or more of the following features: wherein the first and second sets of six cradle attachments include a pair of first cradle attachments, a pair of second cradle attachments disposed rearward of the pair of first cradle attachments, a pair of third cradle attachments disposed rearward of the pair of second cradle attachments, a pair of fourth cradle attachments disposed rearward of the pair of third

cradle attachments, a pair of fifth cradle attachments disposed rearward of the pair of fourth cradle attachments, and a pair of sixth cradle attachments disposed rearward of the pair of fifth cradle attachments. The third and fourth pairs of cradle attachments include fasteners configured to detach under the force of the frontal impact event to allow the engine to displace toward a rear of the vehicle.

In addition to the foregoing, the described system may include one or more of the following features: wherein each of the first and second side rails further include (i) a first collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, wherein the first collapsing feature is located between the second and third cradle attachments along the direction of the longitudinal axis, and wherein the first collapsing feature is configured to collapse the associated first or second side rail in an inboard cross-car direction; (ii) a second collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, wherein the second collapsing feature is located between the third and fourth cradle attachments along the direction of the longitudinal axis, and wherein the second collapsing feature is configured to collapse the associated first or second side rail in an outboard cross-car direction; and (iii) a third collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, wherein the third collapsing feature is located between the fourth and fifth cradle attachments along the direction of the longitudinal axis, and wherein the third collapsing feature is configured to collapse the associated first or second side rail in the inboard cross-car direction.

Further areas of applicability of the teachings of the present disclosure will become apparent from the detailed description, claims and the drawings provided hereinafter, wherein like reference numerals refer to like features throughout the several views of the drawings. It should be understood that the detailed description, including disclosed embodiments and drawings references therein, are merely exemplary in nature intended for purposes of illustration only and are not intended to limit the scope of the present disclosure, its application or uses. Thus, variations that do not depart from the gist of the present disclosure are intended to be within the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a bottom view of an example vehicle structural support system including an engine cradle and side rail assembly in accordance with the principles of the present disclosure;

FIG. **2** is a side view of the engine cradle and side rail assembly shown in FIG. **1**, in accordance with the principles of the present disclosure;

FIG. **3** is a perspective view of the engine cradle shown in FIG. **1**, in accordance with the principles of the present disclosure;

FIG. **4** is a side view of the side rail assembly and engine cradle shown in FIG. **2**, before assembly and in accordance with the principles of the present disclosure;

FIG. **5** is another side view of a portion of the side rail assembly, in accordance with the principles of the present disclosure;

FIG. **6** is a top view of the portion of the side rail assembly shown in FIG. **5**, in accordance with the principles of the present disclosure; and

FIG. **7** is a bottom view of the engine cradle and side rail assembly of FIG. **1** after an example frontal impact event, with the engine cradle transparent, in accordance with the principles of the present disclosure.

DETAILED DESCRIPTION

The present application is directed to a vehicle structural support system configured to absorb impact loads during a frontal impact event. The system includes a front end module with opposed structural side rails each coupled to an engine cradle at six locations. Each side rail includes a crush initiator and three deformation beads, and is configured to detach from the cradle at predetermined locations and bend in a desired inboard or outboard axial direction during the frontal impact event, to thereby reduce deceleration and eliminate passenger compartment intrusion.

With initial reference to FIGS. **1** and **2**, an example vehicle is illustrated and generally identified at reference numeral **10**. The vehicle **10** generally includes wheels **12** and a structural support assembly or system **14** including a front end module (FEM) **16** and a cradle **18**. A front end **20** of the vehicle **10** is illustrated and the vehicle **10** generally extends fore-aft along a central axis 'A' between the front **20** and rear of the vehicle (not shown). An axis 'B' extends cross-car and is orthogonal to central axis 'A'. The illustrated components are configured to provide a structural base for additional vehicle components such as, for example, body panels and a drivetrain.

In the example embodiment, the structural support system **14** further includes a structural side rail assembly **22** including a pair of upper load path beams or main load side rails **24**. The main load side rails **24** extend parallel to or substantially parallel to central axis 'A' and generally include a forward end **26** and an opposite rearward end **28**. The forward end **26** is disposed toward the vehicle front **20** and connected with FEM **16**, and the rearward end **28** is disposed toward the vehicle rear and coupled to a rocker panel (not shown) via an extension **29**. Each of the side rails have similar (e.g., mirror image) parts, thus only one rail **24** will be discussed with reference to both.

With additional reference to FIGS. **4-6**, in the example embodiment, side rail **24** generally includes an inner member or shell **30** (FIG. **5**) and an outer member or shell **32** (FIG. **4**). The inner shell **30** is generally C-shaped and includes a body panel **34** connected between an upper wall **36** and a lower wall **38**. The outer shell **32** includes a generally planar body **40**. Connecting flanges **42** extend outward from and generally orthogonal to the walls **36**, **38**. The connecting flanges **42** are configured to abut with flanges **44** of the outer shell **32** to be connected via spot welding or the like. Additionally, inner and outer shells **30**, **32** may include various stampings **46**, for example, for reinforcement purposes.

In some embodiments, a plate member **47** is coupled (e.g., welded) to the forward end **26** of the main load side rail **24** and is configured to couple to the FEM **16**. The side rails **24** are generally disposed between the front and rear wheels **12** and may define wheel wells and/or include mounting hardware for vehicle shafts and wheels (e.g., control arms, coils, and the like), and other components (not shown). It will be appreciated that rails **24** are not limited to the features shown and described, and may have additional features similar to those described in commonly owned U.S. Pat. No. 10,967,918, issued Apr. 6, 2021, the entire contents of which are incorporated herein by reference thereto. Notably, however, the rails **24** described herein include unique attachment or

coupling features **50** to provide multiple connections to the cradle **18**, as described herein in more detail.

In the example embodiment, each main load side rail **24** is coupled to the cradle **18** at six different locations, and the shape of each main load side rail **24** is configured to facilitate a degree of controlled axial deformation under predetermined loads such as, for example, frontal impacts events. Accordingly, each side rail **24** includes vertically extending collapsing features **52** to facilitate collapsing of the main load side rail **24** to absorb energy during an impact event. In the illustrated example, main load side rail **24** includes two collapsing features **52** formed in/on the outboard shell **32** and two collapsing features **52** formed in/on the inboard shell **30** (see FIG. **2**).

With continued reference to FIGS. **1** and **2**, in the example embodiment, the FEM **16** includes or is connected to a front fascia (not shown), a bumper **54**, and a radiator mount (not shown). The fascia and bumper **54** extend in the general cross-car direction and are configured to couple to the side rails **24** and/or to other structural member of the vehicle chassis. In at least some implementations, the fascia or bumper **54** define the forwardmost portion of the vehicle **10**.

With reference now to FIGS. **1-4**, the cradle **18** will be described in more detail. The cradle **18** is a forward portion of the vehicle chassis or frame and is configured to support the vehicle engine and transmission (not shown). Additionally, the cradle **18** is a structural member coupled to the side rail assembly **22** and configured to transmit loads from the front to rear portions of the chassis. In the example embodiment, the cradle **18** includes a pair of opposed fore-aft oriented rails or members **56**, and a pair of cross-car oriented support rails or members **58**. The fore-aft members **56** are laterally spaced apart in the cross-car direction with one member **56** located on each of the driver and passenger sides of the engine cradle **18**. The fore-aft members **56** include brackets or mounts **60** having upwardly extending portions to provide side rail coupling features **50** on opposite sides of the engine.

To support the mounts **60** and engine, the fore-aft members **56** extend generally beneath the mounts **60**, through a channel defined by the mounts and/or may be coupled to a forward portion of the mounts **60** and extend forwardly therefrom. To support the engine cradle **18** and engine, the fore-aft members **56** and mounts **60** are coupled to the main chassis including the main load rails **24**, as described herein in more detail. As shown in FIG. **1**, in the example implementation, the fore-aft members **56** are received inwardly of the main load rails **24** laterally between the front wheels **12**, and extend forwardly beyond the front wheels **12** toward the bumper **54**. However, it will be appreciated that other orientations are envisioned.

In the example embodiment, the engine cradle cross-car members **58** are laterally spaced apart in the fore-aft direction are coupled at opposed ends to mounts **60** and fore-aft member **56**. The cross-car members **58** are configured to provide support against twisting and lateral (cross-car) movement or bending of the fore-aft members **56** and/or mounts **60**. Additionally, a cross-car support **62** and skid plate **64** are coupled to and extend between the fore-aft members **56** and/or mounts **60** to further increase structural strength. To further improve the structural integrity of the cradle **18** and provide a more robust mount for the engine and more robust chassis, angled support brackets **66** are coupled to and extend between the fore-aft members **56** and cross-car members **58** and/or other chassis components.

With additional reference to FIG. **3**, the cradle **18** further includes a cross rail or member **68** having a main body **70**, a first end **72**, and an opposite second end **74**. In the example embodiment, the cross-member **68** is directly coupled to and extends between the opposed main load rails **24**. As shown, the cross member **68** is connected to a lower side **76** of the main load rails **24** (generally facing the surface on which the vehicle is situated) and is located rearward of the FEM **16** and forward of the engine cradle **18**. The cross-member **68** is located above an upper surface **78** of the fore-aft members **56** and a pair of opposed brackets or braces **80** extend between each of the cross member first and second ends **72**, **74** and respective fore-aft member **56**. Each brace **80** is coupled to a respective fore-aft member **56** via a bracket **82** and is coupled to the cross member **68** directly or via a bracket **84** (FIG. **1**). Further, each brace **80** extends from a respective one of the cradle fore-aft members **56** outwardly toward the adjacent cross member end **72**, **74**, and in at least some implementations, is at an angle to longitudinal centerline axis 'A' of the vehicle of between 0° and 60°, although other arrangements may be utilized.

With continued reference to FIGS. **2** and **3**, each mount **60** includes an attachment arm assembly **90** configured to couple to one of the main load rails **24**. In the example embodiment, the attachment arm assembly **90** includes a forward or first attachment arm **92** extending outwardly from the fore-aft member **56** to a distal end **94**. Similarly, an intermediate or second attachment arm **96** extends outwardly from the fore-aft member **56** to a distal end **98**, and a connecting member **100** is coupled between the distal ends **94**, **98**. A rear or third attachment arm **102** extends outwardly from the second attachment arm **96** toward the vehicle rear to a distal end **104**, and an attachment flange **106** extends outward from the distal end **104**.

It will be appreciated that cradle **18** is not limited to the features shown and described, but may have additional features similar to those described in commonly owned U.S. patent application Ser. No. 16/561,925, filed Sep. 5, 2019, the entire contents of which are incorporated herein by reference thereto. Notably, however, cradle **18** described herein includes two additional connections or couplings, one to each main load side rail **24**.

As shown in FIGS. **1-3**, the cradle **18** includes twelve different locations for attaching to the structural side rail assembly **22**, there being six attachment locations with coupling features **50** for each side rail **24**. With reference to FIG. **3**, the attachment locations of cradle **18** for attaching to the side rail assembly **22** will be described in more detail. In the illustrated example, the cradle **18** includes a pair of first cradle attachments **110** defined by posts **112** and first cradle fasteners **114** (e.g., cradle bolts). One post **112** extends upwardly from each of the cross member ends **72**, **74** and defines an aperture **116** to receive the first cradle fastener **114**. The first cradle attachment **110** couples to the side rail coupling feature **50** at a first location 'L1' (FIG. **2**). A pair of second cradle attachments **118** is defined by posts **120** and second cradle fasteners **122**. One post **120** extends upwardly from each of the braces **80** and defines an aperture **124** to receive the second cradle fastener **122**. The second cradle attachments **118** couple to the side rail coupling feature **50** at a second location 'L2' (FIG. **2**). As shown, the second cradle attachments **118** are positioned rearward and inboard of the first cradle attachments **110**.

A pair of third cradle attachments **130** is defined by the first attachment arms **92** and third cradle fasteners **132**. An aperture **134** is defined in the first attachment arm distal end **94** to receive the third cradle fastener **132**. The third cradle attachments **130** couple to the side rail coupling feature **50** at a third location 'L3' (FIG. **2**). A pair of fourth cradle

attachments **136** is defined by the second attachment arms **96** and fourth cradle fasteners **138**. An aperture **140** is defined in the second attachment arm distal end **98** to receive the fourth cradle fastener **138**. The fourth cradle attachments **136** couple to the side rail coupling feature **50** at a fourth location 'L4' (FIG. **2**).

A pair of fifth cradle attachments **150** is defined by the third attachment arms **102** and fifth cradle fasteners **152**. An aperture **154** is defined in the third attachment arm distal end **104** to receive the fifth cradle fastener **152**. The fifth cradle attachments **150** couple to the side rail coupling feature **50** at a fifth location 'L5' (FIG. **2**). Additionally, as shown in FIG. **2**, the third attachment arm **102** includes a fracture feature **156** configured to fracture during a predefined event, as described herein in more detail. In the example embodiment, the fracture feature **156** (e.g., see FIG. **4**) is defined at least in part by a window **158** and thin bridges **160** connecting the distal end **104** to a proximal end **162**, which are defined and tuned for a specific fracture. A pair of sixth cradle attachments **170** is defined by the attachment flanges **106** and sixth cradle fasteners **172**. An aperture **174** is defined in the attachment flange **106** and is configured to receive the sixth cradle fastener **172**. The sixth cradle attachments **170** couple to the side rail coupling feature **50** at a sixth location 'L6' (FIG. **2**).

With reference now to FIGS. **4-6**, the structural side rail assembly **22** will be described in more detail. The shape of each main load side rail **24** is configured to facilitate a degree of controlled axial deformation and lateral bending under predetermined frontal loads to reduce deceleration without passenger compartment intrusion. Specifically, arranged in order from the side rail forward end **26** toward the rearward end **28**, each side rail **24** includes a crush initiator feature **52***a*, a first bead or collapsing feature **52***b*, a second bead or collapsing feature **52***c*, and a third bead or collapsing feature **52***d*. Such features **52** are configured to facilitate axial collapsing of the side rail **24** during the frontal impact.

In the example embodiment, the crush initiator feature **52***a* includes a plurality of bead features formed on the inner shell **30** and configured to facilitate axial crush of the rail tip up to the first cradle attachments **110**. The first collapsing feature **52***b* is formed on the side rail outboard side **32** (FIG. **4**) and provides a relatively weakened area without reinforcements **46** that is configured to bend the side rail **24** axially inboard under the frontal impact. The second collapsing feature **52***c* is formed on the side rail inboard side **30** (FIG. **5**) and provides a relatively weakened area configured to bend the side rail **24** axially outboard under the frontal impact. The third collapsing feature **52***d* is formed on the side rail outboard side **32** (FIG. **4**) and provides a relatively weakened area without reinforcements **46** that is configured to bend the side rail **24** axially inboard under the frontal impact. One example side rail deformation is illustrated in a comparison between FIG. **1** (before impact) and FIG. **7** (after impact).

With reference now to FIGS. **2**, **6**, and **7**, one example deformation and detachment script of the structural support system **14** will be described. As discussed above, the cradle **18** includes twelve attachments with the side rail assembly **22**, where a first set of six attachments are made with one side rail **24**, and a second set of identical six attachments are made with the other side rail **24**. Advantageously, some of the attachments are designed to intentionally detach during the frontal impact event to allow axial collapse of side rails **24** and to reduce deceleration for improved occupant performance. Additionally, the side rails **24** include four collapsing features, including a crush initiator and three beads, to promote the axial deformation and lateral bending for increased energy absorption.

During the example impact event, such as a frontal impact event, the object first impacts the FEM **16**, which absorbs some of the impact and subsequently transfers load to the forward ends **28** of the main load path side rails **24**. The load then travels through the side rails **24** as described. This initial force from FEM **16** causes rearward movement of the rail forward ends **28**, which first collapse rearward at the crush initiator feature **52***a*. The impact force continues rearward through the side rails **24** toward the first and second cradle attachments **110**, **118**. In the example embodiment, first and second cradle fasteners **114**, **122** are high strength fasteners (e.g., M-14 bolts) and configured to maintain the attachment between the cradle **18** and the side rails **24** during the impact event. The impact force then continues rearward to the first collapsing features **52***b*, which cause the side rails **24** at that location to axially deform and laterally bend inboard to absorb more of the impact.

The impact force continues rearward through the side rails **24** to the third cradle attachments **130**. In the example embodiment, the third cradle fasteners **132** are lower strength fasteners (e.g., M-10 bolts) configured to detach (e.g., shear) under the impact force, thereby separating the third cradle attachments **130**. The impact force then travels rearward to the second collapsing features **52***c*, which cause the side rails **24** at that location to axially deform and laterally bend outboard to absorb more of the impact. The impact force continues rearward to the fourth cradle attachments **136**. In the example embodiment, the fourth cradle fasteners **138** are also lower strength fasteners configured to detach under the impact force, thereby separating the fourth cradle attachments **136**.

The impact force then continues rearward through the side rails **24** to the third collapsing features **52***d*, which cause the side rails **24** at that location to axially deform and laterally bend inboard to absorb more of the impact. The impact force then travels rearward to the fifth cradle attachment **150**. In the example embodiment, the fifth cradle fasteners **152** are high strength fasteners configured to maintain the attachment between the cradle **18** and the side rails **24** during the impact event. However, the impact causes the fracture feature **156** of the cast third attachment arm **102** to fracture, thereby allowing rearward movement of the cradle **18**, which facilitates rail deformation at first collapsing features **52***b* and inboard collapse of the rail at third collapsing features **52***d*. The impact force then travels further rearward to the sixth cradle attachments **170**. In the example embodiment, the sixth cradle fasteners **172** are high strength fasteners configured to maintain the attachment between the cradle **18** and the side rails **24** during the impact event. Additionally, impact force is transferred through the sixth cradle attachments **170** to the cross-car support **62** and skid plate **64** to facilitate moving the cradle **18** rearward and absorb impact energy and improve dynamic crush.

Described herein are systems and methods for a vehicle structure support configured to reduce deceleration and passenger compartment intrusion during frontal impact events. The systems include a cradle attached to a structural side rail assembly at twelve different locations. Some of the attachments are configured to detach during the impact event, and the cradle includes an aluminum cast part configured to fracture between the fourth and fifth attachments, thereby allowing the engine and transmission to displace rearward to improve dynamic crush. Further, main load path side rails of the rail assembly include collapsing features

configured to cause axial displacement and lateral bending of the side rails to further absorb impact energy.

It will be understood that the mixing and matching of features, elements, methodologies, systems and/or functions between various examples may be expressly contemplated herein so that one skilled in the art will appreciate from the present teachings that features, elements, systems and/or functions of one example may be incorporated into another example as appropriate, unless described otherwise above. It will also be understood that the description, including disclosed examples and drawings, is merely exemplary in nature intended for purposes of illustration only and is not intended to limit the scope of the present disclosure, its application or uses. Thus, variations that do not depart from the gist of the present disclosure are intended to be within the scope of the present disclosure.

What is claimed is:

1. A structural support system for a vehicle having a longitudinal axis extending from a front of the vehicle to a rear of the vehicle, the system comprising:

a cradle configured to support an engine of the vehicle;

a structural side rail assembly having first and second side rails;

a first set of six cradle attachments coupling the cradle to the first side rail; and

a second set of six cradle attachments coupling the cradle to the second side rail,

wherein a predetermined portion of the cradle attachments of both the first and second set of six cradle attachments are designed to intentionally detach during a frontal impact event to facilitate absorbing impact energy and reducing deceleration and passenger compartment intrusion, and

wherein the first and second sets of six cradle attachments comprise:

a pair of first cradle attachments;

a pair of second cradle attachments disposed rearward of the pair of first cradle attachments;

a pair of third cradle attachments disposed rearward of the pair of second cradle attachments;

a pair of fourth cradle attachments disposed rearward of the pair of third cradle attachments;

a pair of fifth cradle attachments disposed rearward of the pair of fourth cradle attachments; and

a pair of sixth cradle attachments disposed rearward of the pair of fifth cradle attachments.

2. The system of claim **1**, wherein the third and fourth pairs of cradle attachments include fasteners configured to detach under the force of the frontal impact event to allow the engine to displace toward a rear of the vehicle.

3. The system of claim **2**, wherein the fasteners are M-10 bolts.

4. The system of claim **1**, wherein the first and second pairs of cradle attachments include second fasteners configured to maintain the attachment between the cradle and the first and second side rails during the frontal impact event.

5. The system of claim **1**, wherein the fifth pair of cradle attachments includes fasteners configured to maintain the attachment between the cradle and the first and second side rails during the frontal impact.

6. The system of claim **5**, wherein the fifth pair of cradle attachments further includes an attachment arm with a fracture feature configured to fracture during the frontal impact.

7. The system of claim **6**, wherein the attachment arm is cast with a portion of the cradle and includes a proximal end and a distal end, and

wherein the fracture feature includes a window defined between two bridges connecting the distal end with the proximal end of the attachment arm.

8. The system of claim **1**, wherein the first and second side rails each include a plurality of collapsing features configured to facilitate collapsing of the first and second side rails to absorb energy of the frontal impact event.

9. The system of claim **8**, wherein the plurality of collapsing features comprises:

a crush initiator located at a forward end of each of the first and second side rails;

a first collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact;

a second collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact; and

a third collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact.

10. The system of claim **9**, wherein the crush initiator is located forward of the first cradle attachment along the direction of the longitudinal axis.

11. The system of claim **9**, wherein the first collapsing feature is located between the second and third cradle attachments along the direction of the longitudinal axis, and

wherein the first collapsing feature is configured to collapse the associated first or second side rail in an inboard cross-car direction.

12. The system of claim **9**, wherein the second collapsing feature is located between the third and fourth cradle attachments along the direction of the longitudinal axis, and

wherein the second collapsing feature is configured to collapse the associated first or second side rail in an outboard cross-car direction.

13. The system of claim **9**, wherein the third collapsing feature is located between the fourth and fifth cradle attachments along the direction of the longitudinal axis, and

wherein the third collapsing feature is configured to collapse the associated first or second side rail in an inboard cross-car direction.

14. The system of claim **1**, wherein each cradle attachment of the first and second sets of six cradle attachments includes a bolt coupling the first or second side rail to the cradle.

15. The system of claim **1**, wherein the first and second sets of six cradle attachments are identical.

16. A structural support system for a vehicle having a longitudinal axis extending from a front of the vehicle to a rear of the vehicle, the system comprising:

a cradle configured to support an engine of the vehicle;

a structural side rail assembly having first and second side rails;

a first set of six cradle attachments coupling the cradle to the first side rail; and

a second set of six cradle attachments coupling the cradle to the second side rail,

wherein a predetermined portion of the cradle attachments of both the first and second set of six cradle attachments are configured to intentionally detach during a frontal impact event to facilitate absorbing impact energy and reducing deceleration and passenger compartment intrusion,

wherein the first and second sets of six cradle attachments comprise:

a pair of first cradle attachments;

a pair of second cradle attachments disposed rearward of the pair of first cradle attachments;

a pair of third cradle attachments disposed rearward of the pair of second cradle attachments;

a pair of fourth cradle attachments disposed rearward of the pair of third cradle attachments;

a pair of fifth cradle attachments disposed rearward of the pair of fourth cradle attachments; and

a pair of sixth cradle attachments disposed rearward of the pair of fifth cradle attachments, and

wherein the third and fourth pairs of cradle attachments include fasteners configured to detach under the force of the frontal impact event to allow the engine to displace toward a rear of the vehicle.

17. The system of claim **16**, wherein each of the first and second side rails further includes:

a first collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, wherein the first collapsing feature is located between the second and third cradle attachments along the direction of the longitudinal axis, and wherein the first collapsing feature is configured to collapse the associated first or second side rail in an inboard cross-car direction;

a second collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, wherein the second collapsing feature is located between the third and fourth cradle attachments along the direction of the longitudinal axis, and wherein the second collapsing feature is configured to collapse the associated first or second side rail in an outboard cross-car direction; and

a third collapsing feature configured to facilitate axial collapsing of the associated first or second side rail during the frontal impact, wherein the third collapsing feature is located between the fourth and fifth cradle attachments along the direction of the longitudinal axis, and wherein the third collapsing feature is configured to collapse the associated first or second side rail in the inboard cross-car direction.

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